

The Martian atmosphere is a significant part of the environment that the Mars Exploration Rovers (MER) will encounter. As such, it imposes important constraints on where the rovers can and cannot land. Unfortunately, as there are no meteorological instruments on the rovers, there is little atmospheric science that can be accomplished, and no scientific preference for landing sites.

The atmosphere constrains landing site selection in two main areas, the entry descent and landing (EDL) process and the survivability of the rovers on the surface. EDL is influenced by the density profile and boundary layer winds (up to altitudes of 5 to 10 km). Surface survivability involves atmospheric dust, temperatures and winds.

During EDL, the atmosphere is used to slow the lander down, both ballistically and on the parachute. This limits the maximum elevation of the landing site to -1.3 km below the MOLA reference aeroid. The landers need to encounter a sufficiently dense atmosphere to be able to stop, and the deeper the landing site, the more column integrated atmosphere the lander can pass through before reaching the surface. The current limit was determined both by a desire to be able to reach the hematite region and by a set of atmosphere models we developed for EDL simulations. These are based on TES atmospheric profile measurements (Conrath *et al.*, JGR, 2000), Ames MGCM results (Haberle *et al.*, JGR, 1993), and the 1-D Ames GCM radiative/convective model by J. Murphy. The latter is used for the near surface diurnal cycle. The current version of our model encompasses representative latitude bands, but we intend to make specific models for the final candidate landing sites to insure that they fall within the general envelope.

The second constraint imposed on potential landing sites through the EDL process is the near surface wind. The wind in the lower ~ 5 km determines the horizontal velocity that the landers have when they land. Due to the mechanics of the landing process, the total velocity (including both the horizontal and vertical components) determines whether or not the landers are successful. Unfortunately, the landing system has no easy way to nullify any horizontal velocity imparted by the wind, so the landing sites selected need to have as little wind as possible. In addition to the mean wind velocity, the landing system is sensitive to vertical wind shear in the lowest kilometer or so. Wind shear can deflect the retro rockets (RADs) from their nominal vertical orientation producing unwanted horizontal spacecraft velocities. Both mean velocity and wind shear are dominated by the local topography and other surface properties (in particular albedo and thermal inertia which control the surface temperature). This is seen even in simplified 2-D mesoscale models (Savijarvi and Siili, JAS, 1993). The effects in a fully 3-D model are expected to be even more topographically dependent. In particular there is potential for wind channeling in canyons and other terrain features. Boundary layer winds and wind shear are currently being mod-

eled based on terrestrial data and boundary layer scaling laws modified for Martian conditions. We hope to supplement this with mesoscale model results (from several sources) once the number of landing sites is reduced to a manageable number.

MER uses the Pathfinder airbag landing system, but the rovers are landing at mid-day (~ 2 pm for MER-A and $\sim 12:40$ pm for MER-B) compared with ~ 3 am for Pathfinder. In addition they land at the Spring equinox instead of the Fall equinox. This results in an approximately 1 mbar higher surface pressure, but are otherwise similar dynamically. The change in landing time makes the lower atmosphere during EDL more of an issue. The warmer daytime temperatures tend to make the atmosphere less dense, requiring lower landing altitudes. This effect is compensated for by design changes (larger RADs) to allow landing at higher elevations than considered for Pathfinder. At night the surface-cooled lower atmosphere is stable and, at least in flat regions, there is relatively little wind. During the mid-day, the boundary layer is strongly warmed by the surface and is usually convectively unstable. This leads to both stronger and more variable winds, as demonstrated by features like dust devils.

In addition to atmospheric constraints on potential landing sites due to EDL issues, the atmosphere also affects the landed portion of the mission. On the surface, atmospheric dust affects the rover's solar power supply and temperature and wind affect the thermal environment. Both will have to be evaluated to make sure the rovers can function for the duration of the mission at the desired landing sites.

Atmospheric dust affects rover power by attenuating the radiation falling on the solar panels. This attenuation can be caused by atmospheric dust and by the accumulation of dust deposited on the panels. Atmospheric attenuation can be a problem if the rover finds itself in a local or especially a regional dust storm. Although visible opacities are unlikely to exceed two (unless a major global dust storm is in progress during the early part of the mission), this is sufficient to hinder operations significantly for several days. It should be noted that TES has seen several dust storms in equatorial regions during this season (Smith *et al.*, JGR, 2000) and the Viking landers also saw such storms (Zurek *et al.*, Mars, 1992). Unfortunately there is no good dataset to determine which regions are more likely to have regional or local dust storms. The deposition rate of dust on the solar panels depends on the background dust opacity. As dust appears to be well mixed (at least in the lower atmosphere), the lower the landing site, the higher the opacity and the more deposition. Also, certain regions, in particular inside the large canyons, are often seen to be dustier than others (but not at dust storm levels). It is not clear whether this is just an altitude effect or site specific effect (Ivanov and Muhleman, GRL, 1998).

Near surface temperature and wind directly affect the lander thermal environment. This is especially an issue for ex-

posed items. Both the wind and atmospheric temperature the lander experiences are controlled by the local and regional topography and diurnal ground temperature variations. In particular, depressions (such as craters and canyons) and slopes can generate significant winds due to day/night temperature contrasts and the corresponding pressure and density changes. The atmospheric temperature at the height of interest is controlled by the heat exchange with the surface. The surface temperature is dominated by the insolation, local albedo and thermal inertia. At the height of the rovers, the atmosphere will tend to respond to the surface on time scales of minutes. For the low nighttime wind speeds seen by Pathfinder (1 to 3 m/s, Schofield *et al.*, Science, 1997), this means the air temperature is only affected by the surface properties within a few hundred meters of the lander. We hope to obtain results from

mesoscale models for a few sites of interest, but at present it is not possible to cover all the possibilities. Furthermore, while mesoscale models should be able to simulate regional scale effects, the data (topography, albedo and thermal inertia) required to study so of the more local effects are not available.

Part of the difficulty with landing on Mars is that we have relatively little atmospheric data about the regions of importance for EDL and surface operations. There is the meteorological information from the three previous landers, but they were all landed in "safe" sites so are not necessarily representative more interesting ones. Each successful lander has also created a single atmospheric profile, but the landing systems tend to interfere with good atmospheric measurements at the most critical near surface altitudes. Furthermore, these are some of the most difficult locations to study from orbit.